

Universal Mobile Telephone Service (I)

Part I: From System I to UMTS

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The frequency allocation sell off for the next generation of mobile phones caused a stir this April when the U.K. government scooped £22.48 billion. More recently the German government netted a staggering £31.8 billion in its licence sell off. What new features can we expect from this next generation of mobile phone?

The ETSI or European Telecommunications Standards Institute has defined a technology standard for the third generation of mobile phones called IMT-2000 or *International Mobile Telecommunications 2000*. These pro-

posals have been approved by the ITU and also go by the name UMTS or Universal Mobile Telecommunications System. The main aim of this standard is to ensure global

harmonisation of broadband mobile communications for 3G or Third Generation phones including frequency allocation and data transfer protocols. This will ensure that

UMTS handsets will be compatible in whatever country adopts the network. One of the main goals of the standard is this so called global roaming. You should be able to make calls using a UMTS/IMT2000 mobile phone whether you're in Bratislava or Bridlington. This means that when you sign up for a UMTS phone and are assigned a phone number, it will be a global number. No need to prefix with country codes — you can always be reached on this number.

The theoretical maximum data rate of UMTS is 2 Mbit/s but this can only be achieved under optimum propagation conditions for example if the mobile is operating in a city and is not moving (immobile?). If the mobile is moving relatively slowly (i.e. walking pace) then transmission rates of up to 384 kbit/s are possible. In any case the minimum guaranteed data rate is 128 kbit/s even with the mobile travelling at vehicular speeds.

New UMTS features

Tomorrow's globally roaming UMTS mobile phone will offer many more features than we see on current handsets. Along with SMS and WAP there will be a multitude of multimedia facilities available. At last you should see the introduction of true video phones and video conferencing over a UMTS radio link. High quality music tracks will be downloaded in an instant and short video postcards may be sent to friends. Interactive games with other phone users will be introduced and shopping methods will also be transformed, your UMTS handset will deal with authorisation and payment of purchases. Company reps and service personnel will find that while on the move they have a direct link to the company's intranet. As a UMTS handset moves, its approximate location will also be logged so that when you request information on local restaurants for example or ask for a street map if you are lost you will receive information relevant to your current location. Anyone dealing with Fleet management or deployment of emergency services and those who need to know the whereabouts of the mobile will find this feature useful.

Predicting how a UMTS handset will look is difficult but anyone who has sent an email using a WAP phone will realise that it will need to be equipped with a more convenient method of data entry and will probably evolve along the lines of a portable PC or palmtop.

A glimpse back into the past

Commercial mobile communications systems in the U.K. really began with *System 1* operated by the G.P.O. (see **table 1**). The system had very poor coverage and was not cellular. Each radiophone requires one frequency for sending and one for receiving i.e. four channels in total for a call between two radiophones. With a voice channel bandwidth of 100kHz each call needed 400kHz of the entire network bandwidth. *System 2* was developed but never implemented. *System 3* was later introduced with a reduced voice bandwidth of 25 kHz. Despite the increased capacity it could never keep up with the demand for this system.

The big breakthrough came with the introduction of the first cellular networks. Although the fundamentals of the cellular network had been theorised, it was in 1947 that D.H. Ring of Bell Labs in the USA formalised the cellular concept in a paper. The basic idea is that instead of using powerful transmitters to cover a large area, the area is divided up rather like the hexagonal panels

Abbreviations

2G	Second Generation (Mobile System)
3G	Third Generation (Mobile System)
AMPS	Advanced Mobile Phone System (US analogue cell network)
ANSI	American National Standards Institute (USA)
ARIB/TTC	Association of Radio Industry and Business (Japan)
BW	Bandwidth
CDMA	Code Division Multiple Access
DCS	Digital Cellular System (DCS1800)
DECT	Digital European Cordless Telephone
EDGE	Enhanced Data Rate for GSM Evolution
ETSI	European Telecommunications Standardisation Institute
FDD	Frequency Division Duplexing
FDMA	Frequency Division Multiple Access
FPLMTS	Future Public Land Mobile Telephone System
GMSK	Gaussian Minimum Shift Keying
GSM	Global System for Mobile Communications (originally called: Groupe Speciale Mobile)
GPO	General Post Office (State run predecessor to BT)
GPRS	General Packet Radio Service
HSCSD	High Speed Circuit Switched Data
IMT	International Mobile Telecommunications
ITU	International Telecommunications Union
LNA	Low Noise Amplifier
LO	Local Oscillator
MSS	Mobile Satellite Service
NMT	Nordic Mobile Telephone (Scandinavian analogue cellular net)
NTT	Nippon Telecom & Telegraph Corp. (Japanese analogue cellular net)
PA	Power Amplifier
PCS	Personal Communications System
QPSK	Quaternary Phase Shift Keying
8PSK	8 Phase Shift Keying
SIM	Subscriber Identity Module
SMS	Short Message Service
TACS	Total Access Communication System (U.K.)
TCP/IP	Transport Control Protocol / Internet Protocol
TD/CDMA	Time Division CDMA
TDD	Time Division Duplexing
TDMA	Time Division Multiple Access
TTA	Telecommunications Technologies Association (South Korea)
UMTS	Universal Mobile Telephone Service
UTRA	UMTS Terrestrial Radio Access
WAP	Wireless Access Protocol
W-CDMA	Wideband Code Division Multiple Access, Wideband-CDMA
WRC	World Radiocommunication Conference

of a patchwork quilt. Low power base stations are placed at the centre of each panel or 'cell'. Base stations in adjacent cells are not allowed to use the same frequencies, but these frequencies can be re-used in other non-adjacent cells. The beauty of the system is that if the number of subscribers in a particular area is large, for example in central London, the number of cells can be increased by reducing the cell size and using more, lower powered base stations, thereby increasing the network capacity.

The U.S. company Bell made trials of the first cellular system in 1978 in Chicago but did not start deployment of their *AMPS* (Advanced Mobile Phone System) until about 1983. Meanwhile the Scandinavian countries had installed the first commercial cellular network in 1981. Working at 450 MHz, this first generation analogue mobile phone system was known as *NMT* (Nordic Mobile Telephone) and offered roaming. It was later superseded by a 900 MHz version. In the early 80's the U.K. introduced *TACS* (Total Access Communication System). This is based on the American *AMPS* but is, needless to say, not compatible with it.

The UK government took an unusual step by deciding that the network licences should be awarded to commercial companies rather than a state owned monopoly like the G.P.O. Cellnet and Racal Vodafone were the successful bidders.

TACS operates in the 900 MHz band and uses analogue FM. The frequency bands are divided up using *FDMA* upper and lower bands at 935-960 MHz and 890-915 MHz allow 1000 channels per band with a nominal channel spacing of 25 kHz. The channels are employed as duplex pairs so that if a mobile is receiving a signal in channel 3 of the upper band, it will be transmitting on channel 3 of the lower band. The send and receive signals will therefore always be separated by 45 MHz. Dedicated control channel pairs are included to enable the network to handle mobile registration, 'handover' as the mobile passes from one cell boundary to another, output power adjustment, call tariff logging and more.

A typical cell size has a 1 km radius in urban and 15 km radius in rural environments. Maximum base station power is 100 W and mobiles are restricted to 10 W output power. To handle the ever increasing subscriber base, extra frequencies were later introduced to boost the network capacity. This system became known as *ETACS*. At the time of writing, Cellnet have marked the discontinuation of its analogue network and Vodafone plans to follow suit in the summer of 2001.

WWW Information sources

Organisations:

UMTS-Forum	http://www.ums-forum.org
UMTS-Licence information	http://www.ums-forum.org/licensing.htm
International Telecommunication Union	http://www.itu.int/limt
European Telecommunications Standards Institute	http://www.etsi.org/ums
UK Regulatory authority	http://www.spectrmauctions.gov.uk
Universal Wireless Communications Consortium	http://www.uwcc.com
Third Generation Partnership Project	http://www.3gpp.org

Manufacturers and network operators:

BTCellnet	http://www.btcellnet.net
Ericsson	http://www.ericsson.co.uk
Nokia	http://www.nokia.com
Alcatel	http://www.alcatel.co.uk
Motorola	http://www.motorola.co.uk
Nortel	http://www.nortelnetworks.com
Nippon Telecom & Telegraph Corporation	http://www.nttdocomo.com
Orange	http://www.orange.co.uk
Philips	http://www.pcc.philips.com
Sagem	http://www.Sagem.com
Vodafone	http://www.vodafone-retail.co.uk

During 1990 the GSM Phase 1 specification appeared after its 11 year incubation period with the ETSI. This was the beginning of the 2G or second generation mobile phones and uses digitised speech. One year later Vodafone launched the first U.K. GSM network, and by

1992 coverage was beginning to extend from the large cities and airports into rural areas. The frequency bands used are identical to the *TACS* system (400 *TACS* channels were deliberately reserved for the introduction of GSM). In 1993 and 1994 One2one and Orange respec-

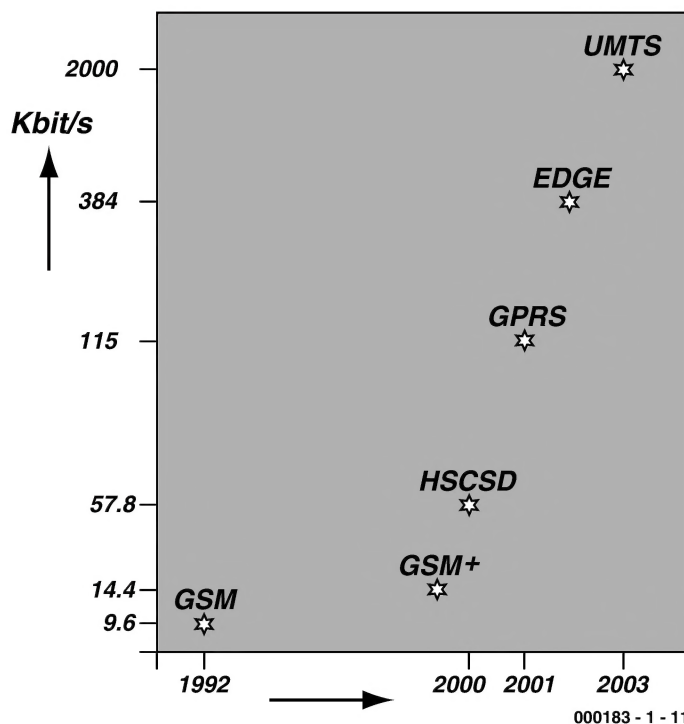


Figure 1. Evolution of GSM to UMTS.

tively launched their GSM system, this time using GSM1800 (otherwise known as PCN or DCS1800) operating in the 1.8 GHz band. 1994 also saw the introduction of the BT Cellnet GSM network in the 900 MHz band. Most current mobiles offer dual-band operation and are therefore compatible with both. This dual-band capability is useful if you intend using the mobile overseas in one of the 110 countries that have adopted GSM, or if your network provider decides in the future to use both bands to solve capacity problems.

In North and South America and in Canada things are a little different. Here GSM1900 operates at 1.9 GHz (also known as PCS1900). Some dual-band mobiles work at GSM900 and GSM1900. Alternatively a tri-band mobile will cover every eventuality. Like TACS, GSM 900 uses FDMA to divide the frequency bands. This time however each of the two bands is divided into 125 channels with a bandwidth of 200 kHz per channel. The 45 MHz duplex spacing is maintained. GSM1800 has 374 channels with a duplex spacing of 95 MHz. In addition to using FDMA to divide up the frequency band into channels, TDMA is used to chop up each channel into contiguous time frames of 4.615 ms. Each frame is further divided into 8 time slots of 0.577 ms. When a mobile is making a call it will be allocated one slot in each frame for sending its digitised voice. Likewise one slot in the receive band is claimed for receiving digitised voice. Mobiles in stand-by mode will only need to listen to certain frames in a paging channel.

Modern GSM mobiles comprise of



two to four highly integrated chipsets. A fully integrated base band chip is under development and coupling this with an HF stage and a few components will allow handsets to shrink in size even further. A relatively new concept is the Dual-mode mobile. This is a GSM mobile phone that can automatically switch into a DECT cordless phone when you are in range of a home base unit (or in the office through the company PABX), thereby making cheaper calls through your cordless phone base unit over a land line. Phones offering this feature have been introduced by Sagem and BT Cellnet.

The success of GSM has been much greater than first anticipated, current estimates indicate approxi-

mately 400 million GSM subscribers worldwide. Forecasts for the year 2010 indicate 1.8 billion subscribers, the greatest growth expected in Asia. In Europe in the coming years the increasing use of multimedia features means that the relatively low data rate of GSM will not be sufficient. We shall look at some of the interim solutions that have been developed to increase the GSM data rate. Its eventual replacement by UMTS will of course allow a maximum data rate of 2 Mbit/s.

One characteristic of multimedia applications is that the volume of data flowing to and from a subscriber is not symmetrical. Unlike speech communication, browsing the Internet will produce far more information passing from the base station to the subscriber (downlink direction) than in the uplink direction. Also unlike speech, the transfer of the data is not real-time critical, it can be sent in

Table I. Mobile radio networks in the U.K.

Generation	Network	Operating	Frequency range	Channel pairs	Channel spacing	Duplex spacing	Modulation
-	System 1	1965	163 MHz	-	100kHz	-	FM, analogue
-	System 3	c.1970	163 MHz	-	25 kHz	-	FM, analogue
1 G	TACS	1985-2000	890 - 960 MHz	1000	25 kHz	45 MHz	FM, analogue
2 G	GSM	1991	880 - 960 MHz	173		45 MHz	GMSK, digital
	PCN(GSM1800)	1993	1710 - 1880 MHz	374	200 kHz	95 MHz	GMSK, digital
3 G	UMTS	2002 ?	1885 - 2025 MHz, 2110 - 2200 MHz	12	5 MHz	190 MHz	WCDMA, digital

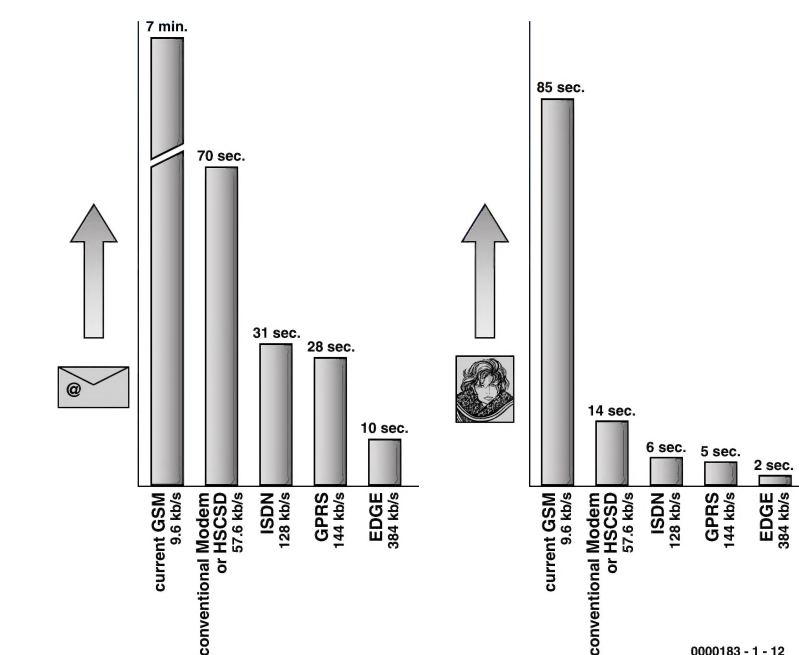
packets which do not necessarily need to be transferred in the correct order. The capacity of the uplink and downlink can be adjusted according to needs.

From GSM to UMTS

The thirst for increased data capacity becomes more apparent year by year. WAP phones are the current fashion but they do not offer any increase in data capacity over the standard 9.6 kb/s. Network providers are implementing various techniques to increase data capacity and bridge the gap between the 9.6 kb/s offered by the 2G GSM phones and the 2Mb/s offered by future 3G phones (see **Figure 1**). Handsets that can use these techniques are known as 2.5G phones. Each of these methods is compatible with the GSM network and does not cause problems with existing handsets.

A standard GSM channel achieves a data rate of 9.6 kb/s with just one time slot in the frequency channel containing 8 timeslots. Altering timeslot allocation is just one method that can be used to increase data capacity. Using a technique called *HSCSD* or *High Speed Circuit Switched Data*, is the simplest and cheapest method for the network operator to increase capacity. It requires only a software update at the base stations. Firstly a more efficient data coding method is used to increase the data rate of each GSM channel from 9.6 kb/s to 14.4 kb/s (so called *GSM+*). Next, four of the eight TDMA timeslots are allocated to one subscriber. This gives a data rate of 57.6 kbit/s. For the user with an HSCSD compliant mobile however this technique has a few disadvantages. Firstly, it takes about one minute to set up the HSCSD call. Secondly, once the connection is established, it acts as a quasi fixed-line in that the four channels are allocated to the subscriber for the duration of the call. The call tariff takes this into account and this method turns out to be expensive for the subscriber. This technique has not been widely deployed in the U.K. but Orange are currently using this method on some of its services.

Another 2.5G system is the *GPRS* or *General Packet Radio Service*. This is a specification produced by the ETSI to provide packet data transfer in a GSM network. This technique can provide a maximum data rate of 171.2 kb/s i.e., three times faster than current modems using a land line! The increased speed is achieved by utilising all 8 slots in a GSM TDMA frame. These would normally be assigned to eight different subscribers. GPRS is actually a universal packet switched data service which overlays the GSM system. It is responsible for packetising data, spreading it



out over free time slots and reassembling it all again at the other end i.e., in the mobile.

A novel feature of this system is its totally different approach to phone use and call billing. The phone is typically switched on in the morning to log on to the network and remains connected for the whole day. Call charges are based on the volume of data sent rather than the connect time. This 'always-on' feature allows almost instantaneous email and web browsing.

BT Cellnet launched their GPRS network in June 2000. Offering a data rate of 28 kb/s, this should be up to 96 kb/s by the new year. Nation-wide coverage was anticipated by September 2000. Orange and Vodafone plan to begin their service before the year end and many European countries have announced similar timescales so GPRS roaming in Europe will be possible. Detractors of the system have pointed out that the claimed data rate of this method is overly optimistic. What happens to all those other 7 subscribers whose timeslots you stole? Well, it seems as though multimedia data flow is typically not continuous but 'bursty'. A screenful of data or a file for example will be downloaded in a burst of activity and then ... silence as we scratch our head and decide which option to select. The silences are used to service other subscribers.

Further enhancement to GSM can also be achieved by using a more efficient method of signal modulation. GSM uses GMSK or Gaussian Minimum Shift Keying, changing this to 8-PSK or eight times Phase Shift Keying increases the capacity of each channel from 9.6 kb/s to 48 kb/s. This technique is used for *EDGE*, or *Enhanced Data rates over GSM Evolution*. Peak data rates of 384 kb/s can be achieved with this system because like GPRS it will use all 8 time slots to send data. GSM/EDGE transceivers will be able to switch between the two modulation modes dynamically to ensure backward compatibility for existing handsets. EDGE provides an evolutionary path from GPRS to UMTS by combining the packet data transfer of GPRS with the modulation method that will be used in the future with UMTS. Integration of this system will be less costly than building the completely new network necessary for UMTS. This system will be offering high speed data links for GSM users before and after the introduction of UMTS and we can be sure to see dual band/dual mode handsets operating between GSM and UMTS in the near future.

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In the second and final part of this article we look at the frequency allocation, licensing and technical background to UMTS.